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UNITED STATES DEPARTMENT OF AGRICULTURE
BUREAU OF HOME ECONOMICS
WASHINGTON, D. C.

SUMMARY OF HOME CANNING EXPERIMENTS SHOWING EFFECT OF DIFFERENT
TIMES AND TEMPERATURES OF PROCESSING ON THE KEEPING
QUALITY OF THE CANNED FOODS

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This report brings together results of experiments on home canning
methods begun by the former Office of Home Economics in 1917 and continued
by the Bureau of Home Economics. These data have furnished the basis of the
published recommendations of the bureau as to times and temperatures for the
processing of the different foods. Some features of the experimental work
required the storing of the canned foods over periods of years, for the
purpose of comparison with others in which spoilage was forced by incuba-
tion. With all the facts in hand, and in view of the considerable varia-
tion that obtains in recommendations for home-canning methods, the bureau
now makes available the detailed data.

The periods of time elapsing between the processing and the opening
of the containers varied from about two months to five years, and averaged
about one year. In general, those opened earliest showed the least spoil-
age, while those stored eight months or longer showed higher percentages
of spoilage. Most of the canned foods were held in the laboratories in
Washington, where room temperatures during the summer are favorable to
bacterial growth.

Bacteriological examinations were made on a part of the canned foods,
but many were given only cursory examinations for the usual signs of
spoilage, such as condition of container, and appearance, odor, and
sometimes flavor of food. It is probable that some of the containers
given rather low scores but not classed as spoiled would have been shown
to be potentially dangerous by bacteriological tests. They are not
recorded here as spoiled. Containers noted as having imperfect closures
are excluded from this summary.

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Table 1. Experimental data on canned foods processed at temperatures near 212°F.

Food	Year canned	Containers in lot.	Blanch- ing period	Cold dip	Processing method	Time of processing	Containers spoiled	
		No.	Min.				No.	%
Asparagus	1920	40 pt.glass	4	Yes	Water bath	2 hrs.	17	42
"		13 " "	4	"	" " 2 T.vinegar	2¼ "	2	15
"		18 " "	4	" ?	Water bath	3 "	3	17
"		4 " "	4	"	" "	1 hr.,3 days intermittent	3	75
"	1921	34 " "	?	?	" "	1 hrs.	13	38
"		36 " "	4	Yes	Water bath 2 T.vinegar	1 "	23	64
"		2 #2 cans	?	?	Water bath	1 "	None	00
"		5 pt.glass	4	Yes	250°F.oven	2 "	3	60
"		6 " "	4	"	350°F. "	2 "	2	33
"	1922	27 " "	3-4	-	Water bath	2 "	None	00
"		44 " "	3-4	-	" "	3 "	8	18
" "		8 " "	4	-	" "	1 hr.,3 days intermittent	2	25
"		8 " "	3-4	-	Water bath 2 T.vinegar	2 hrs.	2	25
Beets	1920	5 " "	10	Yes	Water bath	90 min.	2	40
"	1921	4 " "	10	"	" "	2 hrs..	2	50
"		3 qt.glass	10	"	" "	2½ "	3	100
Carrots	1919	14 " "	?	?	" "	90 min.	1	7
Chard	1919	5 pt.glass	?	?	" "	2 hrs.	None	00
"		4 " "	?	?	" "	1 hr.,3 days intermittent	"	00
Corn	1919	10 " "	5	Yes	" "	2 hrs.	10	100
"		3 " "	5	"	Water bath tomatoes added	2 "	1	33
"		32 " "	5	"	Water bath	3 "	28	87
"		6 " "	5	-	" "	3 "	6	100
"		6 " "	10	Yes	" "	3 "	6	100
"		24 " "	5	"	" "	1 hr.,3 days intermittent	24	100
"		6 " "	5	"	" "	1½ hrs.3 days intermittent	None	00
"		8 " "	5	"	" "	4 hrs.	6	75
"		2 " "	5	"	" "	5 "	1	50
"		3 " "	10	"	" "	6 "	1	33
"		6 " "	5	"	" " 2T.vinegar 2 T. sugar	3 "	4	67
"		1 " "	5	"	Water bath 4 T.vinegar 2 T.sugar	3 "	None	00
"		2 " "	5	"	Water bath 6 T.vinegar 2 T. sugar	3 "	"	00

Table 1 - Continued

Food	Year canned	Containers in lot	Blanching period	Cold dip	Processing method	Time of processing	Containers spoiled	
		No.	Min.	..		.	No.	%
Corn	1921	3 pt.glass	5	Yes	Water bath	2 hrs.	2	67
"		1 #2 can	?	"	" "	3 "	1	100
"		2 " "	?	?	" "	6 "	None	00
"	1922	36 pt.glass	3-5	-	" "	4½ "	33	92
Lima Beans	1919	6	?	?	" "	3 "	6	100
"		11	?	?	" "	4 "	5	45
"		7	?	?	" "	1 hr.,3 days intermittent	7	100
"		13 qt.glass	5	Yes	" "	3 hrs.	12	92
"		8 " "	5	"	" "	4 "	8	100
"	1920	13 " "	5	"	" "	3 "	12	92
"		8 " "	5	"	" "	4 "	8	100
"		6 #2 cans	5	"	" "	5 "	3	50
"		13 qt.glass	5	"	" "	5 "	9	69
"		5 #3 cans	5	"	" "	5 "	2	40
"	1921	5 qt.glass	?	?	" "	2 "	5	100
"		10 " "	?	?	" "	3 "	9	90
"		10 " "	?	?	" "	4 "	9	90
"		27 " "	?	?	" "	5 "	9	33
"		6 " "	?	?	" "	6 "	None	00
"		7 " "	?	?	" "	2 "	1	14
"		5 " "	?	?	2 T.vinegar Water bath	3 "	5	100
"		4 " "	?	?	2 T.vinegar Water bath	4 "	None	00
"		11 #3 cans	?	?	2 T.vinegar Water bath	5 "	7	64
"	1922	12 pt.glass	10	-	2 T.vinegar Water bath	3 "	7	58
"		6 " "	-	-	" "	4 "	4	67
Peas	1919	4 qt.glass	-	-	" "	1½ "	4	100
"		4 " "	-	-	" "	2 "	None	00
"		3 " "	5	-	" "	2 "	2	67
"		3 " "	5	Yes	" "	2 "	3	100
"		5 " "	10	-	" "	2 "	5	100
"		3 " "	10	Yes	" "	2 "	None	00
"		14 #2 cans	?	?	" "	2 "	5	36
"		27 pt.glass	?	?	" "	3 "	20	74
"		2 qt. "	5	Yes	" "	3 "	None	00
"		26 " "	10	-	" "	3 "	25	96
"		10 " "	10	Yes	" "	3 "	2	20
"		12 #2 cans	?	?	" "	3 "	9	75
"		5 #3 "	5	-	" "	3 "	4	80
"		6 qt.glass	5	-	" "	1 hr.,3 days intermittent	6	100
"		3 qt. "	5	"	" "	6 hrs.	None	00
"		3 " "	-	-	Open kettle	1½ "	3	100

Table 1 continu·

Food	Year canned	Containers in lot	Blanching period	Cold dip	Processing method	Time of processing	Containers spoiled No.	%
		No.	Min.				No.	%
Peas	1919	4 qt.glass	-	-	Open kettle / Water bath	30 min / 30 "	4	100
"		6 " "	-	-	Open kettle / Water bath	60 " / 30 "	6	100
"		6 " "	-	-	Open kettle / water bath / 2 T.vinegar	30 " / 30 "	6	100
"		6 " "	-	-	Water bath / 2 T.vinegar	1 hr.	6	100
"	1920	44 " "	3-5	-	Water bath	2 "	38	86
"		5 " "	5	-	" "	1 hr.,2 days intermittent	5	100
"		6 #2 cans	5	-	" "	3 hrs.	6	100
"		27 qt.glass	3-5	-	" "	3 "	22	81
"		12 " "	5	-	" "	4 "	12	100
"	1921	15 pt. "	?	?	" "	2 "	8	53
Spinach	1919	15 qt. "	5	Yes	" "	2 "	14	93
"		7 " "	5	"	" "	3 "	7	100
"		3 " "	5	"	" "	3 "	3	100
"		1 " "	5	"	" "	4 "	1	100
"	1920	12 " "	5	-	" "	2 "	12	100
"		6 " "	5	-	" " / 1 T.vinegar	2 "	5	83
"		12 " "	5	-	Water bath	3 "	7	58
"		6 #3 cans	5	-	" "	3 "	3	50
"		6 qt.glass	5	-	" "	4 "	3	50
String beans	1919	12 pt. "	5	-	" "	1½ "	11	92
"		6 " "	-	-	" "	2 "	6	100
"		26 " "	5	Yes	" "	2 "	13	50
"		87 " "	5	-	" "	2 "	65	75
"		4 " "	5	-	Steam	2 "	2	50
"		5 " "	Salt water	Yes	Water bath		None	00
"		13 " "	10	"	" "	2 "	12	92
"		5 " "	10	-	" "	2 "	4	80
"		4 " "	-	-	Open kettle / Water bath	1 " / 30 min.	2	50
"		6 " "	5	Yes	" "	3 hrs.	None	00
"		9 " "	5	-	" "	3 "	3	33
"		4 " "	5	-	" "	1 hr.,3 days intermittent	None	00
"	1920	50 qt. "	5	Yes	" "	2 hrs.	47	94
"		39 " "	5	"	" "	3 "	20	51
"		5 #2 cans	5	"	" "	3 "	2	40
"		10 qt.glass	5	"	" "	1 hr.,3 days intermittent	7	70
"	1921	12 #2 cans	?	?	" "	2 hrs.	None	00
"		19 #2 "	?	?	" "	3 "	"	00

Table 1. Continued

Food	Year canned	Containers in lot	Blanch- ing period	Cold dip	Processing method	Time of processing	Containers spoiled	
		No.	Min.				No.	%
String beans	1922	24 pt. glass	?	?	Water bath	3 hrs.	None	00
Squash	1919	7 qt. "	?	?	" "	3 "	1	14
summer		4 " "	?	?	" "	1 hr.,3 days intermittent	None	00
Sweet potatoes	1919	18 " "	5	–	" "	3 hrs.	14	78
Beef	1920	4 pt. "	–	–	" "	1½ "	3	75
"		22 " "	–	–	" "	3 "	9	41
"		15 " "	–	–	" "	4 "	3	20
"		14 " "	–	–	" "	6 "	2	14
Chicken		5 " "	–	–	" "	1½ "	5	100
"		14 " "	–	–	" "	3 "	7	50
"		26 " "	–	–	" "	4 "	15	58
"		31 " "	–	–	" "	5 "	17	55
"		17 " "	–	–	" "	6 "	3	18
Clams		15 #2 cans	–	–	" "	3 "	15	100
"		7 " "	–	–	" "	4 "	7	100
"		8 " "	–	–	" "	6 "	8	100
"		3 pt. glass	–	–	" "	6 "	3	100
Halibut		14 #2 cans	–	–	" "	3 "	14	100
"		4 " "	–	–	" "	4 "	2	50
Perch roe		4 " "	–	–	" "	3 "	4	100
Rockfish		2 pt. glass	–	–	" "	4 "	2	100
Lamb and		4 " "	–	–	" "	3 "	4	100
mutton		8 " "	–	–	" "	4 "	00	00
"		3 " "	–	–	" "	6 "	00	00
Total		1542 containers					925	60

Table 2. Experimental data on canned foods processed in a water bath by the one-period and intermittent methods [1]

Vegetable	One-period method				Intermittent method				Total containers	Total containers spoiled	
	Containers in lot No.	Time of processing Hours	Containers spoiled No.	%	Containers in lot No.	Time of processing Hours	Containers spoiled No.	%	No.	No.	%
1917 [2]											
Carrots	14	1½	1	7	0	-----	0	00	14	1	7
Corn	25	3	10	40	22	1-1-1	15	68	47	25	53
Lime beans	6	3	6	100	7	1-1-1	7	100	24	18	75
Lime beans	11	4	5	45	0	-----	0	00			
Peas	17	3	0	00	16	1-1-1	0	00	33	0	00
String beans	35	2	5	14	31	1-1-1	1	3	66	6	9
Summer squash	7	3	1	14	8	1-1-1	0	00	15	1	7
Swiss chard	5	2	0	00	5	1-1-1	0	00	10	0	00
1918											
Corn in quart glass	69	3-6	59	86	33	1-1-1-1 / 1½-1½-1½	26	79	102	85	83
Corn in pint glass	23	2½-5	16	70	17	1-1-1	9	53	40	25	63
Lime beans	89	2-5	15	17	24	1-1-1 / 1½-1½-1½	0	00	113	15	13
Peas	88	2-3	9	10	6	1-1-1	0	00	94	9	10
Spinach	113	2-3	57	50	16	1-1-1	6	38	129	63	49
String beans	111	2	50	45	0	-----	0	00	111	50	45
String beans	10	3	0	00	18	1-1-1	0	00	28	0	00

1/ This work was done in part at the Office of Home Economics in Washington, D.C.; in part at Cornell University, Ithaca, N.Y., in collaboration with the Department of Home Economics; and in part in the field (Texas, Louisiana, and North Carolina.)

2/ Records do not show the size and kind of containers used for part of the foods described in this table.

Table 2. Continued

Vegetable	One-period Method — Containers in lot No.	Time of processing Hours	Containers spoiled No.	Containers spoiled %	Intermittent method — Containers in lot No.	Time of processing Hours	Containers spoiled No.	Containers spoiled %	Total containers No.	Total containers spoiled No.	Total containers spoiled %
1919											
Corn	0	–	0	00	49	$1\frac{1}{2}$-$1\frac{1}{2}$-$1\frac{1}{2}$	35	71	49	35	71
						$1\frac{1}{2}$-1-1					
Lima beans quart glass	(47	3	14	30	0	-----	0	00	106	15	14
	(12	4	1	8	24	$1\frac{1}{2}$-1-1	0	00			
						$1\frac{1}{2}$-$1\frac{1}{2}$-$1\frac{1}{2}$					
Peas quart glass	(23	5	0	00	0	-----	0	00	62	9	15
	(28	2	4	14	6	1-1-1	0	00			
	(28	3	5	18	0	-----	0	00			
Spinach	(108	2	48	44	24	1-1-1	9	38	153	66	43
	(17	3	9	53	0	-----	0	00			
	(4	4	0	00	0	-----	0	00			
String beans	(105	2	52	50	0	-----	0	00	133	52	39
	(10	3	00	00	18	1-1-1	0	00			
1920											
Asparagus #2 pt.	50	2	13	26	0	-----	0	00	127	17	13
#2 pt.	11	2	2	18	0	-----	0	00			
qt.	45	3	1	2	21	1-1$\frac{1}{2}$-1	13	5			
Corn qt.	49	4-6	47	96	pt.18	1-1-1	0	72	73	66	90
pt.	6	5	6	100	0	-----		0			
Lima beans qt.	59	3-6	20	34	24	$1\frac{1}{2}$-1-1	1	4	83	21	25
						$1\frac{1}{2}$-$1\frac{1}{2}$-$1\frac{1}{2}$					
Peas qt.	42	3-4	29	69	19	1-1-1	13	68	61	42	69
						$1\frac{1}{2}$-$1\frac{1}{2}$-1					
Spinach qt.	51	2-4	24	47	12	1-1-1	10	83	63	34	54
						$1\frac{1}{2}$-$1\frac{1}{2}$-$1\frac{1}{2}$					
String beans qt.	(72	2	52	72	0	-----	0	00	156	79	51
	(64	3	20	31	20	1-1-1	7	35			
Totals	1454		581	40	438		153	35	1892	734	39

Table 3. Experimental data on canned foods processed in the steam pressure canner

Food	Year canned	Containers in lot	Blanch-ing period	Cold dip	Pressure	Time of processing	Containers spoiled	
		No.	Min.		Lbs.	Min.	No.	%
Asparagus	1920	4 pt. glass	4	Yes	5	60	0	00
"		3 " "	4	"	10	60	0	00*
"	1922	5 " "	3	---	10	30	1	20
"		10 " & qt."	3	---	10	30-35	0	00
"		6 #2 cans	-	---	10	35	0	00*
"		3 pt. glass	3-4	---	10	45	0	00*
"	1923	6 #2 cans	0-3	---	10	35	0	00*
"		11 " "	0-3	---	10	40	0	00*
"	1925	16 pt. glass	3-4	---	10	30	3	19
"		18 " "	3-4	---	10	35	1	6*
"		12 " "	3-4	---	10	40	0	00*
"		7 " "	3-4	---	10	45	0	00*
Beets	1921	2 qt. "	10	---	5	60	1	50
"		1 " "	-	---	5	90	0	00
"	1922	6 #2 cans	0-10	---	5	60	0	00
"		6 " "	0-10	---	10	40	1	17*
Corn	1919	2 #2 cans	5	---	5	75	1	50
"		6 " "	5	---	5	90	0	00
"		4 qt. glass	5	---	10	60	0	00
"		8 #2 cans	5	---	10	60	0	00
"		5 " "	5	---	15	20	5	100
"		7 " "	5	---	15	50	4	57
"		9 qt. glass	0-5	---	15	80	1	11
"	1921	23 #2 cans	5	---	5	90	2	9
"		16 " "	5	---	10	60	0	00
"	1922	24 pt. glass	5	---	15	60	4	17
"		10 " "	5	---	15	70	0	00
"		24 qt. "	5	---	15	70	4	17
"		12 " "	5	---	15	90	0	00*
Lima beans	1919	5 " "	5	---	5	90	0	00
" "		4 " "	5	---	10	45	0	00
" "		4 " "	5	---	10	60	0	00*
" "		6 #2 cans	5	---	10	60	0	00*
" "		5 #3 "	5	---	10	60	0	00*
" "	1920	9 qt. glass	5	---	5	90	0	00
" "		3 " "	5	---	10	45	0	00
" "		7 #2 cans	5	---	10	60	0	00*
" "		4 #3 "	5	---	10	50	0	00
" "		3 " "	5	---	10	60	0	00*
" "	1922	4 pt. glass	12	---	10	45	0	00
" "		14 " "	10-12	---	10	60	2	14*
" "		4 qt. "	12	---	10	60	1	25*
Peas	1919	3 qt. "	5	---	5	90	1	33
"		4 #3 cans	5	---	5	90	2	50
"		3 qt. glass	10	---	10	45	0	00
"		4 " "	10	---	15	40	0	00*

*Asterisks indicate processes that are equivalent in temperature to present day processes.

Table 3. Continued

Food	Year canned	Containers in lot	Blanching period	Cold dip	Pressure	Time of processing	Containers spoiled	
		No.	Min.		Lbs.	Min.	No.	%
Peas	1920	5 qt.glass	3	--	5	60	1	20
"		5 #2 cans	5	--	5	75	0	00
"		4 qt.glass	3	--	5	90	0	00
"		8 #2 cans	5	--	10	30	0	00
"		5 qt.glass	3	--	10	45	2	40
"	1922	8 #2 cans	0-3	--	10	25	5	63
" , large		10 pt.glass	0-5	--	10	40	7	70
"		13 " "	0-5	--	10	50	0	00*
Spinach	1919	4 qt. "	5	--	5	60	1	25
"		2 " "	5	--	5	75	0	00
"		5 #2 cans	5	--	5	75	0	00
"		3 qt. glass	5	--	10	30	0	00
"		7 " "	5-15	--	10	40	3	43
"		6 #3 cans	5	--	10	40	0	00
String beans	1919	5 qt.glass	5	--	5	90	0	00
" "		5 " "	5	--	8	50	0	00
" "		5 " "	5	--	10	30	0	00
" "		5 " "	5	--	10	40	0	00*
" "	1920	3 " "	5	--	5	90	0	00
" "		3 #2 cans	5	--	5	90	0	00
" "		3 #2 "	5	--	10	40	0	00*
" "	1921	2 " "	5	--	5	90	0	00
" "		3 " "	5	--	5	90	0	00
" "		2 " "	5	--	5	105	0	00
" "		27 pt.glass	5.	--	10	45	0	00*
Sweet potatoes	1920	3 qt.glass	-	--	5	90	0	00
" "		9 " "	0-14	--	10	40	0	00
" "		4 " "	. -	--	15	70	0	00
Beef	1920	3 pt. "	Seared	--	5	120	1	33
"		8 " "	Raw and seared	--	10	60	4	50
"		27 " "	"	--	15	30	4	15
"		4 " "	Seared	--	15	50	0	00*
"		4 " "	"	--	15	60	0	00*
"		8 " "	"	--	20	75	0	00*
Chicken	1920	5 " "	"	--	5	30	0	00
"		6 " "	"	--	5	60	1	17
"		12 " "	Raw and seared	--	5	90	1	8
"		8	"	--	5	120	1	13
"		19 " "	"	--	10	60	1	5
"		4 " "	"	--	13	30	3	75
"		36 " "	"	--	15	30	17	47
"		25 " "	"	--	15	60	0	00
"		6 " "	"	--	20	30	2	33
"		5 " "	"	--	20	75	0	00

Table 3. Continu...

Food	Year canned	Containers in lot	Blanch-ing period	Cold dip	Pressure	Time of processing	Containers spoiled	
		No.	Min.		Lbs.	Min.	No.	%
Chicken	1922	23 pt.glass	Raw and seared	---	15	60	5	22
Lamb and mutton	1920	1 " "	Seared	---	5	120	0	00
"		10 " "	"	---	15	30	0	00
"		10 " "	"	---	15	60	0	00*
"	1926	8 " "	"	---	15	40	0	00
"		8 " "	"	---	15	50	0	00*
Pork	1922	6 " "	"	---	15	90	0	00*
Sausage	1922	21 " "	"	---	15	90	0	00*
Totals		783 containers					93	.12

As these tables show, considerable variation occurred from year to year in the same kind of food materials canned in a similar manner, and there were other seemingly inexplicable variations during a single season. These may be due to differences in the number or kinds of bacteria originally present in the different lots, or to variations in the food materials themselves.

The following observations are made from Table 1:

Corn canned with tomatoes and processed only two hours kept as well as corn alone which was processed six hours. For this vegetable canned alone, the longer periods of four, five, and six hours were more effective than two and three hours. The addition of as much as 4 and 6 tablespoons of vinegar to a pint jar prevented spoilage, but this much acid decidedly changes the flavor of the corn.

Lima beans show high percentages of spoilage with even as much as five hours in a water bath. One small lot given six hours did not show spoilage.

Peas and spinach gave high percentages of spoilage in most lots.

When string beans were processed in pint glass jars or No. 2 cans, two and three hours sometimes entirely prevented spoilage.

Cold dipping of vegetables after blanching did not give as good results as packing hot.

The meats and fish processed in a water bath showed heavy spoilage.

The comparison of continuous processing with intermittent processing shown in Table 2 covers investigations made during four years, and includes 1,892 glass jars and tin cans of vegetables. Of those given one period, 40 per cent spoiled, while of the ones given intermittent processing, 35 per cent spoiled. However, only about one-third as many containers were processed by the intermittent method as by the one-period method.

The combined totals from Tables 1 and 2 make an aggregate of 3,434 jars and cans of food, most of which were processed in a water bath. This method as well as the other methods used for these groups gives inside the food container temperatures not higher than the boiling point of water. Of the 3,434 jars and cans of food, 1,659 or 48 per cent showed spoilage. Experience has shown that serious cases of food poisoning may result from the consumption of canned non-acid foods which have been processed at temperatures around 212°F.

Of the 783 jars and cans processed by steam under pressure, 93 or 12 per cent spoiled. (Table 3.) However, since the processing periods used were in many cases less than are now recommended for the nonacid foods, 12 per cent spoilage is undoubtedly higher than would be obtained by present-day methods. When only those processes are considered which were equivalent in temperature to present methods, the figures for spoilage become 5 out of 240 containers, or 2 per cent. Temperatures within containers of food processed by steam under pressure reach 240°F. when the pressure is held at 10 pounds, and 250°F. when the pressure is held at 15 pounds.

Summary

Experiments continued over a period of 10 years in the canning by household methods of 4,217 jars and cans of nonacid foods indicate a very decided advantage in favor of steam-pressure canning as compared with water-bath canning for such food materials.

Variations in spoilage occurring from year to year and in some cases within the same year indicate differences in the number or kinds of bacteria originally present, or variations in the food materials themselves.

The foods most frequently lost were meats and fish, corn, lima beans and peas.

The hot packing of vegetables resulted in less spoilage than cold packing.

Additions of small quantities of acid in some cases seemed to reduce spoilage, although this appears not to be dependable.

A comparison of continuous and intermittent water-bath processing shows in numerous instances lower percentages of spoilage in the intermittent process, but many more samples were canned by the continuous method.

All these data are strong evidence of the need of high temperatures for the canning of foods low in acidity.